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Procedia Engineering 29 (2012) 2693 – 2698

Procedia Engineering

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2012 International Workshop on Information and Electronics Engineering (IWIEE)

Envelope Extraction of Anaesthesia Breathing Sound Signal on Hilbert Huang Transform

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Abstract

On the analysis of the traditional envelope extraction method of anesthesia respiratory sound on Hilbert Transform, proposed the improvement extraction method of breathing sound signal envelope based on Hilbert Huang Transform (HHT). Using the parabola parameter spline interpolation method to fit the signal extremum points, after fitting the request signal is obtained by Empirical Mode Decomposition (EMD) from the curve, and then signal envelope is extracted by Hilbert Transform. Finally the obtained conclusion is compared with the traditional envelope extraction method of Hilbert Transform and the envelope extraction method of complex Morlet wavelet. The method can be used in the signal processing of operation breathing monitor, in order to be able to help doctors monitor the respiratory status of operation patient more accurately.

Keywords:Anaesthesia breathing sound; HHT; Tidal Volume; Medical signal processing

1. Introduction

Breathing sound is a physiological acoustic signal in the ventilation process between outside and human respiratory system. It is associated with pathophysiological relevance of respiratory sound science, has become the important research topic in clinical medicine. There are many differences in different time-domain waveform of breathing sound signal and different converted waveform, the waveform of the

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doi:10.1016/j.proeng.2012.01.374

differences can be used to describe the envelope[1]. Extracting envelope of breathing sound, and carrying on the analysis, the result can be used as typical features for classification and recognition[2,3].

Usually, operation treatment can play a very good result for various diseases, but if the process of operation monitor is poor, it may lead to various complications that have even threatened the life of the patient. On operation, the vast majority of deaths associated with anaesthesia event relate to the process of poor operation monitor. Therefore, doctors devote more and more attention in respiratory monitoring for anesthetic patients. Monitoring of anaesthesia breathing sound signal is mainly reflected through the Tidal Volume and changes of oxygen saturation. When the patient changes in the process of operation or faces up to the possibility of respiratory emergency situations, the first change is Tidal Volume. Tidal Volume is usually refers to each inhaled or exhaled gas in the resting state. This medical characteristics can associated with the signal envelope in breath sound signal processing. Each respiratory cycle signal envelope area is proportional to each respiratory cycle of Tidal Volume. According to the state of anaesthesia breathing signal envelope, the changes of Tidal Volume can be known, it can help doctors monitor the respiratory state of the patient effectively in the process of operation.

Currently the most commonly used envelope extraction method of breathing sound signal is Hilbert Transformation. Because of high-order harmonic will be inevitably extracted from the approach, result contains a lot of high-frequency components and produces too much burr. Li Shengjun[4] proposed the use of complex Morlet wavelet to extract the envelope, although this method overcomes the glitch of Hilbert Transform, wavelet analysis of signal processing often need to verify. Based on non-stationary, non-linear method of signal proposed by Dr. Huang Ne[5], the envelope of anesthesia breathing sound signal is extracted by Hilbert-Huang Transform.

HHT is proposed by Dr. Huang E for analyzing non-stationary signals. This method was first proposed in 1998 and has been widely recognized in recent years, it is used in many ways, such as seismic data analysis, the heart sound signal analysis, and machine fault diagnosis. Compared with traditional methods of data processing, its main innovation is the introduction of Empirical Mode Decomposition method and proposing the concept of Intrinsic Mode Function (IMF). Through the EMD process, the target signal is broken down into the IMF, then each IMF is analyzed by Hilbert Transform Spectrum[6], we can get meaningful instantaneous frequency, finally, the precise frequency of non-stationary signal is expressed.

2. Envelope extraction method of anaesthetic breathing sound signal

Envelope extraction of anaesthetic breathing sound signal is mainly divided into two processes.

2.1 Pretreatment of anaesthetic breathing sound signal

Before envelope extraction of the breathing sound signal by Huang Transform, the signal is pre-processed first. There are two purposes: first, to remove all kinds of noise signals of breathing sounds; second, the breathing sound signal is converted into a single component signal.

The source signal is assumed $x(t)$, $x(t)$ is converted by Huang Transform for the following steps[5]:

(1) First, extreme points of $x(t)$ are determined, the parabola parameter spline interpolation method is used to fit the signal maxima and minima points, maximum envelope $x_{\max}(t)$ and minimum envelope $x_{\min}(t)$ of $x(t)$ are obtained.

(2) Finding the mean lines $m(t)$ between $x_{\max}(t)$ and $x_{\min}(t)$:

$$m(t) = [\, x_{\max}(t) + x_{\min}(t) \,] / 2 \tag{1}$$

$h(t)$ is obtained by $x(t)$ minus the mean line $m(t)$.

(3) If $g(t)$ conforms to IMF conditions, go to step (4),else repeat steps (1) and (2) until qualified $g(t)$ is found.

(4) So $c_1(t)$ is equal to $g(t)$, $c_1(t)$ is the demand of the IMF which is called Intrinsic Mode Function. Residual $r_1(t)$ is calculated as:

$$r1(t) = x(t) - c1(t) \tag{2}$$

(5) Residual $r_1(t)$ is seen as a new source signal, then the above steps are repeated until the information of residual $r_n(t)$ influence content of the study weakly or $r_n(t)$ is a monotone function. After that, stop the decomposition process. The results of this procedure can be:

$$x(t) = c1(t) + r1(t) \tag{3}$$

$$r1(t) = c2(t) + r2(t) \tag{4}$$

$$\dots$$

$$rn(t) = cn\text{-}1(t) + rn\text{-}1(t) \tag{5}$$

EMD is the process that the residual $r_n(t)$ is separated continuously, then Intrinsic Mode Function is got. And with the increase of the order of IMF, the frequency of $c(t)$ decreases. Noise signal of breathing sounds include high-frequency (1500 ~ 3000*Hz*) and low frequency (50 ~ 150*Hz*). To get rid of these two types of noise, only the Intrinsic Mode Function whose average instantaneous frequency in the 100 ~ 1200*Hz* range is retained. The request signal is obtained from the sum of retained Intrinsic Mode Function.

The following is comparison between a cycle of breathing sound signal before and after filtering by the above method of waveform:

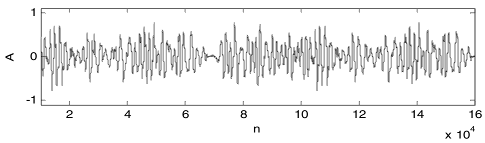


Figure 1: Normal breathing sound waveform

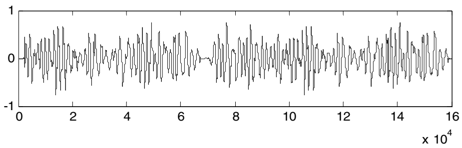


Figure 2: The filtered signal waveform

It can be seen in the filtered signal, the two types of noise are removed effectively. And the EMD algorithm is adaptive and do not need to verify. The filtered signal waveform is more efficient and accurate than ordinary direct limit frequency filtering method.

2.2 Envelope extraction of signal

Through Hilbert Transform, a real signal can be expressed as an analysis signal whose spectrum has the only value of positive frequency domain. That is significant to the envelope of instantaneous signal.

The breathing sound signal $x(t)$ transformed by Hilbert Transform is denoted by $H[x(t)]$ or $x^{\wedge}(t)$, $x^{\wedge}(t)$ is defined as

$$x^{\wedge}(t) = H[(t)] = \int_{-\infty}^{\infty} \frac{x(\tau)}{(t - \tau)} \tag{6}$$

The nature of the Hilbert Transform is an ideal 90-degree phase shifter. Signal $x(t)$ is as the real part, Hilbert Transform of x(t) is as the imaginary part. The real part and the imaginary part constitute the complex signal $z(t) = x(t) + j^{\wedge}(t) = x(t) * h(t)$,and $h(t) = \delta(t) + j(1/\pi t)$. For narrowband signal $x(t)$, the analog $x(t)$is the envelope of the source signal, as

$$\left| x^{\wedge}(t) \right| = \sqrt{x^2(t) + x^{\wedge 2}(t)} \tag{7}$$

And $h(t)$ is called Hilbert envelope filter. Its Fourier transform as follows:

$$h(t) = 1 + j \left| -j \; sgn(t) \right| = \begin{cases} 0 \\ 2 \end{cases} \tag{8}$$

The essence of complex signal *z(t)*is use *h(t)* to filter negative frequency components of *x(t)* and the phase remains unchanged. As the anesthesia breathing sound signal has been transformed by HHT, high-frequency noise is filtered; the signal envelope is smoother than before.

After HHT treatment, the anesthesia breathing sound signal envelope as follows:

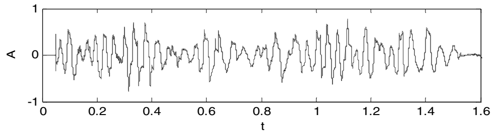


Figure 3: The filtered breathing sound signal waveform.

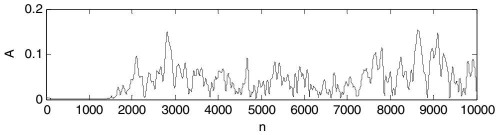


Figure 4: The Hilbert envelope waveform

From the two figures above, the signal envelope is smooth and less burr after Hilbert Huang Transform.

3. The method validation

To verify the feasibility of this method, the following figures list the results of anesthesia breathing sound signal processing in two cases. The figure 5 and figure 9 are filtered by HHT method; the figure 6 of group one and figure 10 of group two are filtered by ordinary method (low-pass filter cut-off frequency is 1500*Hz*, high pass filter cut-off frequency is 30*Hz*), then extracted the envelopes by Hilbert Transform; the figure 7 of group one and figure 11 of group two are filtered by ordinary method, then extracted the envelopes by complex Morlet wavelet transform; the figure 8 and figure 12 are extracted the envelopes by method above.

First group: Normal breathing sound.

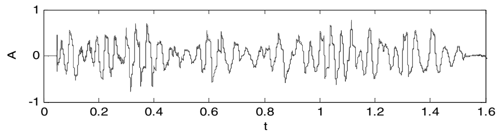


Figure 5: The filtered signal waveform by HHT method.

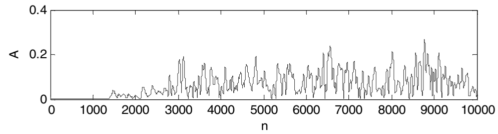


Figure 6: The signal envelope waveform by Hilbert Transform.

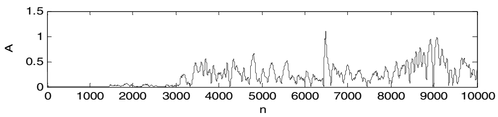


Figure 7: The signal envelope waveform by complex Morlet transform.

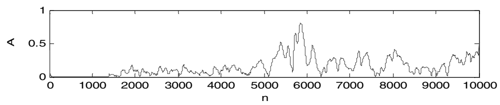


Figure 8: The signal envelope waveform by HHT method.

Second group: Low-key dry rale breathing sound.

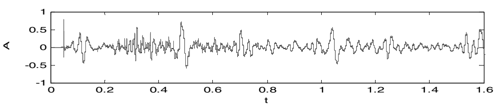


Figure 9: The filtered signal waveform by HHT method.

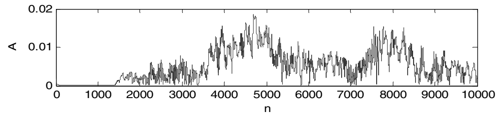
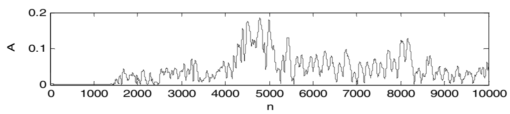


Figure 10: The signal envelope waveform by Hilbert Transform



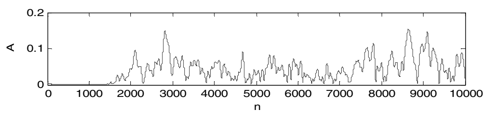


Figure 11: The signal waveform by HHT method.

Figure 12: The signal waveform by HHT method.

Through the comparison of figures can be seen: As the interference signal is simple filtered out by Hilbert envelope extraction method, so that there are too many unwanted signals and more burr, therefore the obtained signal envelope is not very good information on the performance of the original signal. Even if the envelope is relatively smooth by complex Morlet wavelet, because of the wavelet need to be repeatedly selected, it is hard to decide which wavelet is the most applicable. From the experimental results, the complex Morlet wavelet apply to the anesthesia patient whose lung is diseased, but when patient's lung is no lesion, the envelope lost part of signal information, it shows that the wavelet doesn't apply to this situation. The HHT extraction method is superior to the former two methods in the signal smooth degree and retention of source signal effective information.

4. Conclusion

This paper proposes the use of Hilbert Huang Transform to extract the signal envelope of anesthesia breathing sound. Through breathing sound signal pretreatment by Huang Transform, it is not only effectively to remove the unwanted signals, but also retain the basic features of anesthesia breathing sound and obtain the effective envelope. And without additional signal as a reference, the method is fast and effective. Compared with extracting envelope method of Hilbert and wavelet, the envelope is fewer burrs by HHT and adaptive to a "base" which is called IMF operated by screening processes. In comparison, wavelet must be pre-selected; it may not apply to different situations. And this method does not require verifying the effectiveness of "base"; it can greatly reduce the workload and improve accuracy. Effective signal envelope of anesthesia breathing sound will help for further calculation of Tidal Volume. According to the experimental data, the method has been verified effective to extract the signal envelope. During the surgery, this method can monitor the Tidal Volume of patient much better, assist doctors monitor patients' respiratory function status, then detect and predict the risk of patient early. That will provide significant help for enhancing the quality of surgery. And during the process in acquiring EMD, parabolic spline interpolation method is used to fit extreme points. Compared with cubic spline interpolation and piecewise power function interpolation, it has a good smoothness and flexibility and avoids the overshoot phenomenon. To the method of extracting the envelope by HHT transform, there are more worthy of further exploration and mining the potential value of superior performance in respect of breathing sound signal analysis and feature extraction.

Acknowledgments

This work was supported by Harbin Technology Innovation Talents Special Foundation of China (2011RFQXS086), Heilongjiang Province Science Foundation of China (QC2010062).

Reference

[1]Sovijärvi A R A,Malmberg L P.Characteristics of breath sounds and adventitious respiratory sounds[J].Eur Respir Rev,2000, 10(77):591-596.

[2]Pasterkamp H,Carson C,Daien D,Oh Y.Digital rspirosonography.New images of lung sounds.Chest,1989,96:1405-1412.

[3]Meslier N,Charbonneau G,Racineux J.Wheezes.Eur Respir J.1995,8:1942-1948.

[4]Li Shengjun. Envelope extraction method of respiratory sounds. Computer Engineering and Applications, 2008, 44(32): 151-154.

[5]Huang NE,Long SR,Shen Z,et al.The empirical mode decomposetion and the Hilbert spectrum for nonlinear and non-stationary time series analysis[J].Proc R Soc Lond A, 1998, 454 (1971):903-995.

[6]Niu Haijun,Wan Mingxi,Wang Supin,Zhao Shouguo.Bispectrum Estimation of Diversified Lung Sounds. Chinese Journal of Scientific Instrument. 2001,22(5):486-489.